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# Design and implementation of MOC Supporter: software system supporting management of change to realize flexible procedure control and accurate cause analysis

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## Abstract

Changes in criteria, procedure and method of maintenance or design of chemical and nuclear plants caused large-scale accidents in the past. That results in that emphasis on Management of Change (MOC) led to formulating guidelines such as Process Safety Management (PSM), which increased ability to prevent accidents. However, MOC does not appear to have performed appropriately due to issues such as lack of recognition of MOC and execution burden. This avoidance of MOC led in insufficient accumulating and sharing of information for the target changes, which resulted into fails not to prevent accidents.

Therefore, we researches MOC Supporter software system which supports execution of MOC. There are several features of our system, the most point is that our system can change procedures of MOC flexibly and control them by IDEF0 model called Plant-LCE. This mechanism enables you to analyze cause more correctly by log data which recorded procedures of implementation of MOC in an investigation of occurred accident.

This paper reports on proposal and evaluation for our procedure to accumulate log, and the design and implementation for development of MOC Supporter.

*Keywords:* Management of Change (MOC), Data Archiving, Process Safety Management (PSM), Lifecycle Engineering (LCE)

## 1 Introduction

Large-scale facilities such as chemical and nuclear plants are prone to accidents due to changes in facility maintenance, repair and other processes. A solution for the problem is Management of Change (referred to as MOC hereafter), which is a methodology to manage changes such as processes and equipment for preventing accident or improving quality of products. MOC is important but there is a problem that MOC is not executed properly.

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example of an accident resulting from incomplete MOC is the Flixborough [1] chemical plant explosion accident that left 28 dead and 89 injured. The main cause of the accident was the lack of consideration given to the impact of folding the pipework installed to connect the reactors, which led to shear fracture. The change was not perceived as MOC and this lack of awareness led to the accident. In Japan too, there is growing concern that MOC is not properly implemented. As accidents occurred in the past due to MOC neglect, it is difficult to say that similar accidents will not recur. There may be accumulated issue on change management hidden below the surface if including near-miss cases.

MOC procedures are necessary to clarify the scope for manager to be able to implement properly it. However, creating such guidelines independently in each organization is a great burden. Therefore, the Division of Safety of the Society of Chemical Engineers of Japan has formulated a technical report of MOC for Japanese [2] which all businesses available. Under the current conditions, MOC implementation support software as a solution that generalizes MOC implementation was considered. Procedural implementation support, log accumulating and management support by such an MOC support system can lower the threshold for implementation of MOC, turn implementation of appropriate MOC into customary, and help to archive and share log.

This paper reports about our proposal for a procedure to archive log, and evaluates whether the log obtained by our procedure can be used to backward trace realizing an accurate cause analysis, and the design and implementation for our software MOC Support after our presentation [3].

## 2 Research scope and related works

First, this section explains a positioning of this research from a social perspective. The US Occupational Safety and Health Administration (hereafter, OSHA), American Institute of Chemical Engineers (referred to as AIChE hereafter) and other organizations have formulated various guidelines and are striving to improve security level. Among these guidelines, they defined Process Safety Management (referred to as PSM hereafter). OSHA/PSM listed "Management of Change" at OSHA 1910.119 (l) as one of 16 items which is "requirements for preventing or minimizing the consequences of catastrophic releases of toxic, reactive, flammable, or explosive chemicals [4]".

In addition, the Division of Safety of the Society of Chemical Engineers of Japan defined 13 remarkable factors having been subdivided from "Management of Change" of OSHA 1910.119 (l) in the technical report of MOC [2]. "6. Management of documents" and "11. Management of log" listed in it should be in charge of computer not people, because computer is superior in deal with the two factors.

Somebodies with same viewpoints mentioned above released each software supporting MOC [5, 6]. However, these system seem mainly to apply checklist procedure to manage changes, it cannot record the order of management. On the other hand, the advantage of our system can control the procedure of MOC, as described at Section 4.1.2-(i).

## 3 Our Study

This chapter describes our studies on MOC which were the basic theories for developing a MOC support software system.

### 3.1 Methodology of our study

To analyze in accordance with the PDCA cycle defined by OSHA/PSM, Shimada et al.[7] suggested the Business Process Model (BPM) which uses the IDEF0 model notation to define the procedures for MOC. IDEF0 is aggregation for Integration Definition for Function Modeling which is a common modeling technique for the analysis, development, re-engineering, and integration of information systems, business processes or software engineering [8]. The IDEF0 method builds models by linking activities which box is a basic diagram as illustrated in Fig. 1. Activities include tasks / operations (steps to be taken). Shimada's BPM is called Template for the Business Process Model (referred to as Template BPM hereafter) [7]. A Template BPM with the flatted basic diagrams of one layer only is shown in Fig. 3. Moreover, Template BPM is a hierarchical arrangement of multiple layers as shown in Fig. 2, which enables fine control of the described procedures from general to very detailed. The advantages of using Template BPM for descriptions include simplification of definition and ease of revise.

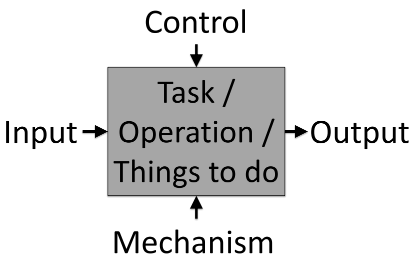


Figure 1: Scheme of activity box that is a basic diagram in the IDEF0 method

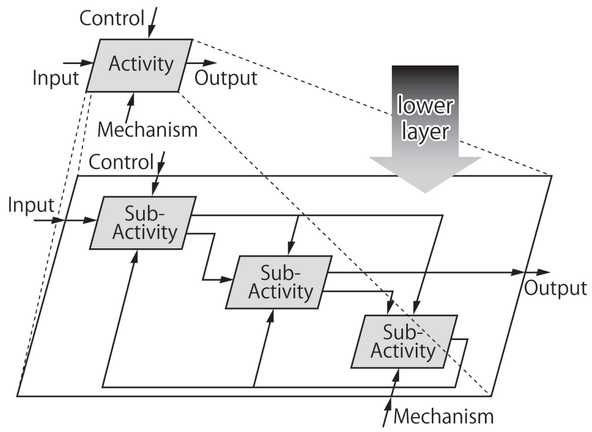


Figure 2: Scheme of multi-layer mechanism in Template BPM

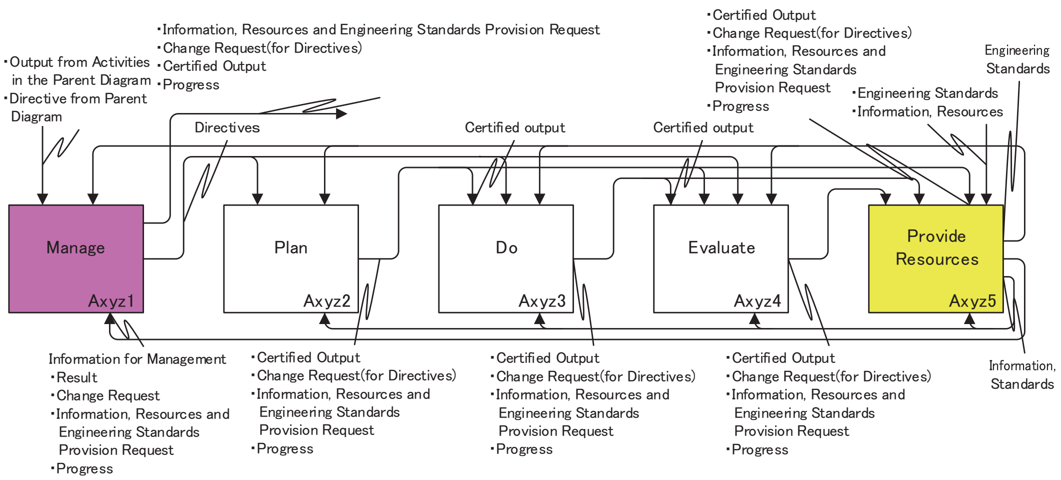


Figure 3: Flatted Template BPM on one layer only [9]

## 3.2 Whole phase for our Management of Change

This section shows whole phase to execute MOC procedures based on Template BPM as in three phases from 1) to 3) below.

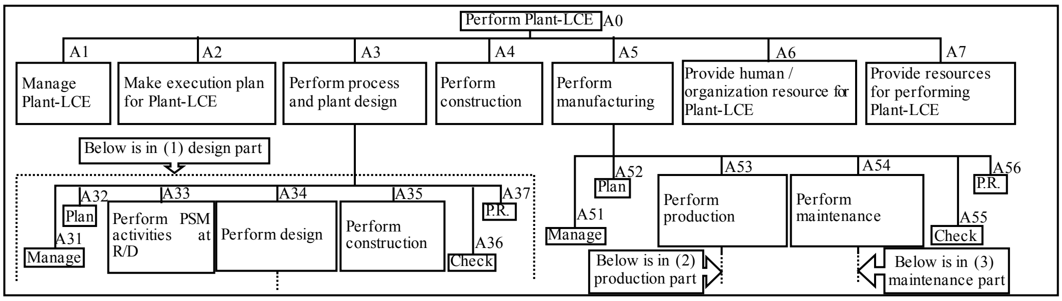


Figure 4: Overview of PSM activities with plant-LCE[10]

1) Build Plant-LCE

Plant-LCE, is abbreviation of Life-Cycle Engineering for industrial Plant. Plant-LCE is a kind of engineering to manage lifetime of an industrial plant, and manages not only production design and product management but also maintenance of product and disposal for the plant. A Plant-LCE data is used in this study as a manual which indicates MOC procedures in industrial plants such as nuclear or chemical plants. Plant-LCE is created based on the Template BPM method which is hierarchy mechanism that consists of activity boxes, shown in Fig. 2. Our developed Plant-LCE consists of mainly into three parts: (1) design of plant, (2) production, and (3) maintenance. A part of the Plant-LCE including the three parts are shown in Fig. 4.

2) Implement MOC in order of activities on Plant-LCE

Start to implement MOC from the first activity A0 of Plant-LCE. The tracing order is based on Template BPM. For example, the order is A0, A1, A2, A3, A31, A32,.... The analysis skips activities that accord with no change or changes regarded as RIK. The proposal procedure to implement MOC was described in Section 4.2.

# 4 Research

## 4.1 Problems, solution, advantage and benefit

### *4.1.1 Problem and solution using system for MOC*

This section explains the benefits of MOC's software support as follows, referring to prob-lems in MOC implementation.

(a) Providing various assistance leading to reduce burden

The most reason why offices avoid implementing MOC seems to be due to low cost effectiveness. To solve this problem and increase spread of MOC, the cost reduction, enlightenment and effective improvement of software system for MOC are necessary. The software system has capability to play role instead of human staff to guide executing procedures and manage documents and log on MOC. If the system works instead of human staff, their load can be reduced.

(b) Improvement for effect and benefit, and expansion of applications
Business manager may not take account for effectiveness of MOC, other than the direct effectiveness above-mentioned (a) because MOC is indirect measure for safety which is counter measure after accident, and does not born benefit directly. The solution to promote MOC software system and ensure safety using MOC is to increase merit of MOC support system and make user agree with its benefit. Potentials of MOC system which enables to increase merit are shown in below.

- The realization of third party inspection to prevent accidents or troubles
  The executor of this third party inspection is supposed a person or AI or both. The miss detecting technology for AI is thought to be realized such as the pattern matching by comparing extracted data from log and documents with the past other text resources. If an inspector can prevent user to wrong based on past data, MOC keeps safe in your business and its worth is increased.
- Statistical visualization of work results to help grasp business effort
  Statistical visualization contributes to improve effectiveness of business. Its realiza-tion requires log and documents of MOC implementation, and a software subsystem which is good at dealing with a lot data in point of good cost effectiveness.
- Sophistication of technology for user support to reduce workers load such as decision making and complement

### *4.1.2 Advantage of our proposal mechanism*

This section explains advantages of our system compared with the conventional system mentioned in Chapter 2.

(i) Flexible function to change procedure of MOC
This system can change the procedure to implement MOC by Plant-LCE unlike other checklist-based support systems. That means its mechanism can change MOC procedures flexibly according to your business rules. That is, our system with its mechanism can be adopted and infiltrates deeply into various business compared with the check list method.

The realization of control procedures of MOC can clarify the turning point that a re-analysis affects on procedures because even if an issue occurs during MOC, it is sufficient to re-analyze only the activities that affect consistency of this analysis. For example, as shown in Fig. 5, when returning from activity 3 to activity 1, a re-analysis is required for activity 1, 2, 3 again. That is because the modification in activity 1 affects the subsequent steps. On the other hand, checklist method cannot realize this mechanism because it does not manage procedure of MOC.

(ii) Advanced log archiving including the procedure order to have executed MOC
The advantage of this system can keep the result of execution including MOC proce-dure as log. Backward trace is an analysis method to reveal accident cause by tracing back in time. If procedures order of executed MOC were not recorded, backward trace cannot apply, so recording procedure order is important. If you can get the execution procedure from the log, you can identify which activity caused the

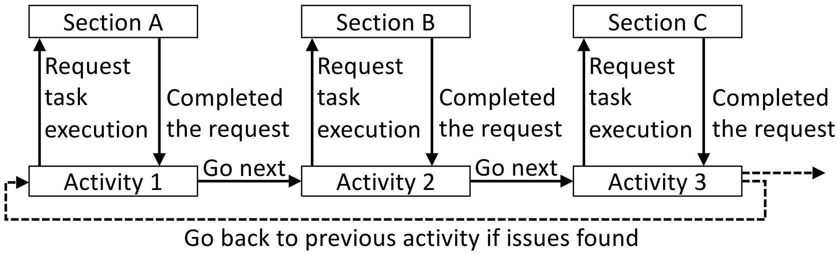


Figure 5: Conceptual diagram on going back to a previous activity if an issue occurs

problem and realize more accurate cause analysis through backward trace. Cause analysis has problem to have ended to individual responsibility as human factor, and causes misfortune and sadness to the related people mostly. However our system may prevent the sad result.

In addition, this feature has an advantage to become compliance assurance. The log or documents under no management of software system may not be accurate due to factors such as human error, falsification. Although it is staff who selects the activity and decides the transition destination even in a MOC support system, the log that the system recorded is difficult to be tampered due to its log be safekeeping generally in a safety store like as a server room. In addition, changes of log via the system leaves evidences on the changes into system log. The mechanism can reveal whether the log was tampered or not. Therefore, this is our system can guarantee the validity of the procedure to have implemented MOC, and that leads to compliance assurance.

### *4.1.3 Effect to install a software system for MOC*

To understand effects to install MOC system, this section explains how much level of MOC reaches after installed MOC system. The levels which have defined based on Table 1 are shown in List 1. We argue that an installation of software system of MOC reaches level 4 on our List 1 because the system satisfies the requirement of the level 4 that users execute MOC procedures based on rules defined inside the system and log is accumulated.

Table 1: Comparison between levels

| Level | Exec[1] | Doc[2] | Rule[3] | Log[4] | Fit[5] |
|---|---|---|---|---|---|
| 1 | N | N | N | N | NA |
| 2 | Y | B | N | N | NA |
| 3 | Y | Y | B | N | NA |
| 4 | Y | Y | Y | Y | B |
| 5 | Y | Y | Y | Y | Y |

Y:Yes, N:No, B:Both (Ambiguous answer)

[1] Whether MOC has been executed?

[2] Whether documents on MOC have been made and managed?

[3] Whether rules on MOC have been defined and followed?

[4] Whether log have been stored and managed?

[5] Does your MOC software system adapt highly to your business?

List 1 Level on implementation of MOC

Level 1 MOC has not been implemented at all.

Level 2 Change may be documented, but MOC is implemeneted each time without rule.

Level 3 MOC is implemented based on rules in point of efficiency and accuracy.

- This background is to define and use the rules of MOC to solve the issues that the acquired results such as documents of MOC were not unified due to no the rules and the inefficiency for repeat execution.

Level 4 Set of log data are accumulated steady by sophisticated rules based execution.

- If the rules are undefined, the writing of log is not unified. So log requirement was in higher level than the rule requirement.

Level 5 Administration under control of an MOC software system dedicated to your business.

- This is most efficient and less waste. However the cost is very expensive.

### 4.2 Method to archive log executed MOC

This method was proposed for a MOC system to store log including execution procedures when user (staffs or operators) implemented MOC, which was defined as the below steps. The flow chart was shown in Fig. 6.

Step 1 Preparation
Input process name and summary of this MOC.

Step 2 Request to input results
This step is a process requests user to input results such as detail of change, inves-tigation, reason not to change. The process is changed depending on the conditions shown below.

Step 2-1 Skip input or not
First, our system judges to skip input or not depending on the current activity. For example "P.R." activity is skipped. Because "P.R." activity is a process phase for system to arrange and store the inputted data of the activities in the current layer, so user has no need to input.

Step 2-2 Request to input executed results according to RIK
User determines whether or not "Replacement-in-Kind (hereafter RIK)". RIK indicates the replacement with same or same type of one on conditions, specifi-cations, design and so on for device, equipment, method and so on. If the user judges that a task done on the current activity matches RIK, the reason needs to be input. If it does not match RIK, input or update the result of tasks such as investigation, execution or changes and so on.

Step 2-3 Input changes
User inputs the detail of change which is not RIK on devices, equipments, procedures and so on. After that, go to Step 3.

Step 2-4 Input reasons
User inputs the reason why this change was regarded as RIK. After that, go to Step 3.

Step 3 Shift into next activity

Shift into a next activity as follows steps.

Step 3-1 Automatic shift

Automatic shift is a state not to require selection of a next activity to user. For example, the state is in shift into "P.R." activity or into an activity which has a path to a lower layer. If the current process matches above-mentioned conditions, go to Step 2 without asking.

Step 3-2 Determine whether completed or not

If the current activity was back to the start activity such A0 after all activi-ties were traced necessary to complete this operation, this operation is finished. That indicates that there is no more discussion or investigation to do for this operation. If not completed, go to Step 2.

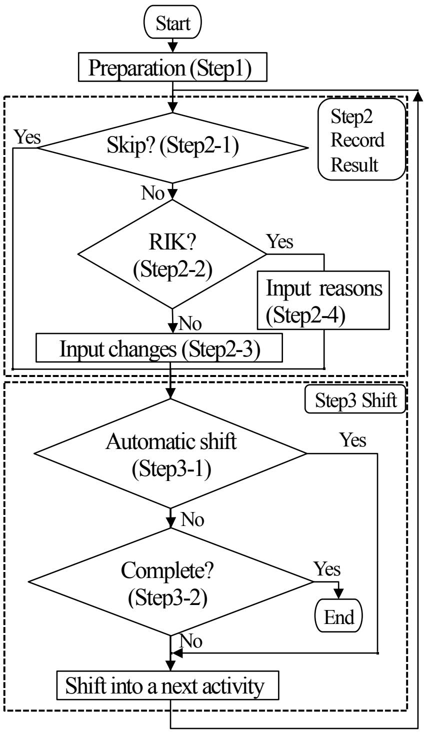


Figure 6: Flowchart of our method

## 4.3 Our developed MOC software system

The system configuration of our MOC software system is shown in Fig. 7. In the preparation, the administrator registers Plant-LCE data to this system. After that, staffs input data according to each Form UI corresponding with the process of each step described in Section 4.2. The data input in each Form UI are stored to DB. The system can show process results executed MOC in reverse time series so that it helps the staff to analyze the cause of MOC if any abnormality or problem occurs.

The principal Form UIs are shown in Fig. 8 and Fig. 9. Fig. 8 is a Form UI which requests to input corresponded with Step 2. There the“Label of Activity”shows the current activity highlighted and all activities. If the change or update on the current activity coincides with RIK, the staff checks the checkbox UI, and inputs the reason judged as RIK into the field“Changed Contents”. If it is not RIK, the staff inputs the operation contents on change or update into it.

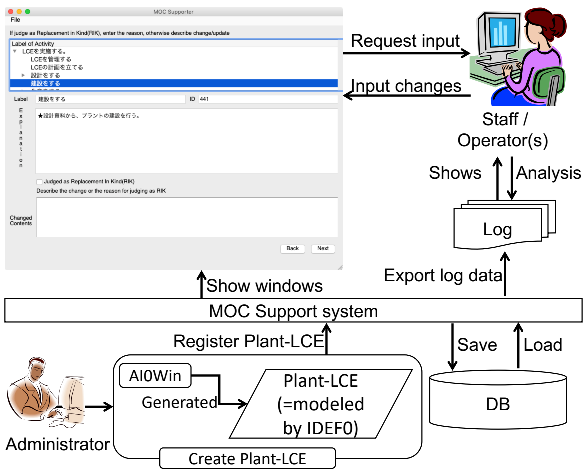


Figure 7: System configuration

Fig. 9 is a Form UI which requests to select the next activity. The staff checks the checkbox UI which indicates the next activity and inputs the reasons for selection or no

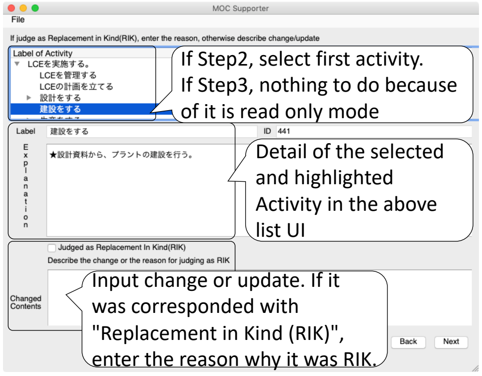


Figure 8: UI to input or update on change

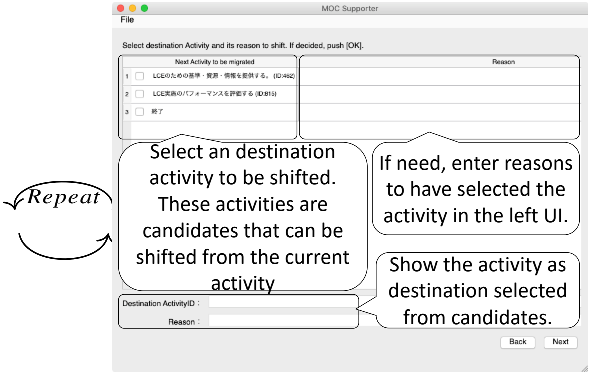


Figure 9: UI to select next activity

selection for each activity.

The tree view UI located in the upper section in Fig. 8 shows activities in Plant-LCE. The data of Plant-LCE is required for our system as mentioned in Section 3.2. The model data of Plant-LCE is loaded from an XML format file created with AI0Win [11]. This system was developed by Python and Qt Toolkit.

## 5 Evaluation

This chapter describes the evaluation result of whether or not our method can store log in a same quality to experts analysis, especially whether log can be used for backward trace.

### 5.1 Target Case

The subject of this evaluation is a case [2] in which the minimum flow rate was changed in a gasoline desulfurizer that removes sulfur content of gasoline fraction produced by a fluid catalytic cracking (FCC) unit.

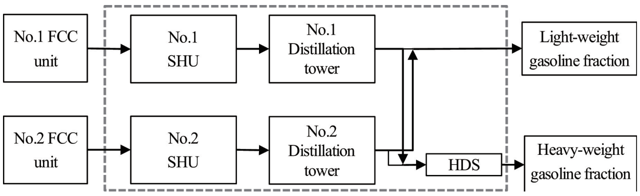


Figure 10: Gasoline desulfurization system line

The flow outline of the gaso-desulfurizer in this case is shown in Fig. 10. There are two FCC units, and the gasoline fractions produced in each FCC unit are sent to selective hydrogenation units (SHU) of No.1 and No.2 to perform the reaction above-mentioned. The gasoline fractions reacting in the SHUs are separated into light and heavy gasoline fractions in separate distillation towers, and heavy gasoline fractions from each tower are sent to the single line hydro desulfurization (HDS) section where desulfurization is carried out. Considering this situation, the result was a request from the driver to change the minimum throughput of the gasoline desulfurizer for the following purposes: reducing slop feed at the start of operation and eliminating energy loss due to recycling and removing instability factors of the unit.

The minimum throughput of this gasoline desulfurizer had been set at 70% of the designed maximum capacity by licensor recommendation, but after reconfirmation of the minimum flow rate by the design department with the licensor, the licensor conducted testing with the actual machine and requested confirmation of drift inside the reactor. As a result of testing, no drift was found inside the reactor, and it was judged that minimum throughput could be lowered. In this case, after carrying out MOC one more time, necessary standards were revised.

Table 2: First stage log

| Common items | | Expert analysis | | Our method | | |
|---|---|---|---|---|---|---|
| #1 | Activity to implement | #2 | Expert's action log | #3 | Step | System recorded log |
| 1 | | 1 | N/A | 1 | 1 | Input name and {1} as summary on this change |
| | | 2 | Record "Request to investigate operating requirement when decreasing flow such as upstream FCC is alive only one line" (as {1}) | 2 | 2 | Skip; ∵ only shift to below layer due to the protocol |
| | | 3 | Select A1 and shift into it | 3 | 3 | Same as expert execution result in the left column |
| 2 | A1 Manage LCE | 4 | Record "Request to determine scopes (e.g. minimal operation term, precondition, request from administrator)" (as {2}) | 4 | 2 | No; Input {2} |
| | | 5 | Select A2 and shift into it | 5 | 3 | Same as expert execution result in the left column |
| 3 | A2 Plan LCE | 6 | Record "Instruct mitigation measures for LP constraints" (as {3}) | 6 | 2 | No; Input {3} |
| | | 7 | Select A3 and shift into it. | 7 | 3 | Same as expert execution result in the left column |
| 4 | A3 Design for LCE | 8 | Skip | 8 | 2 | Skip; ∵ only shift to below layer due to the protocol |
| | | 9 | Select A31 and shift into it. | 9 | 3 | Same as expert execution result in the left column |
| 5 | A31 Manage of design | 10 | Skip | 10 | 2 | Skip; ∵ only shift to next activity due to in the manage activity |
| | | 11 | Select A32 and shift into it | 11 | 3 | Same as expert execution result in the left column |
| 6 | A32 Deciding whole design concept | 12 | Record "A conclusion that minimal operation shifts to 50kL/h (62.5%) which is lower than previous min criteria 56kL/h (70%, max is 80kL/h)). In addition, input studied result: Continuing operation is main objective in case flow decreases such as one upstream of FCC only is alive. Minor remodeling (change of bypass, control loop etc.) may be considered but major remodeling not." (as {4}) | 12 | 2 | No; Input {4} |
| | | 13 | Select A33 and shift into it | 13 | 3 | Same as expert execution result in the left column |
| 7 | A33 Design process concept | 14 | Record "A conclusion verifying the material balance based on actual result of verification process, which examines material balance in case the minimum throughput of this gasoline desulfurizer decreased to 50 kL / h and correctly estimates the reduction effect." (as {5}) | 14 | 2 | No; Input {5} |
| | | 15 | Select A39 and shift into it | 15 | 3 | Same as expert execution result in the left column |

## 5.2 Evaluation Results

The case of Section 5.1 was analyzed based on both our system following the method described in Section 4.2 and traditional manner by experts who belongs the Division of Safety of the Society of Chemical Engineers of Japan, and that acquired two set of log. The total number of activities which experts analyzed the case was 136.

The result to compare the two set of log data was shown in Table 2 and Table 3. Table 2 showed the analyzed result at first stage from activity 1 to activity 7. Table 3 showed the analyzed result at final stage from activity 132 to activity 136. The middle log data between Table 2 and Table 3 was omitted due to the paper space limitation.

Each column on the second row of Table 2 or Table 3 from the left means as follows. "#1": activity number or log number accorded with the next right cell...(1); "Activity to implement": activity of Plant-LCE that arranged in order of implementation... (2) ; "#2" : same meaning to "#1"...(3) ; "Expert's action log" : log

Table 3: Final stage log

| Common items | | Expert analysis | | Our method | | |
|---|---|---|---|---|---|---|
| #1 | Activity to implement | #2 | Expert's action log | #3 | Step | System recorded log |
| 132 | A531 Manage production execution | 1 | Record "investigated result of what can be changed inside safety operational criteria" (as {a}) | 1 | 2 | No; Input {a} |
| | | 2 | Select A56 and shift into it | 2 | 3 | Same as expert execution result in the left column |
| 133 | A56 Providing criteria, resource, information for production | 3 | Skip | 3 | 2 | Skip; this activity coincides with "provide resource" |
| | | 4 | Select A51 and shift into it | 4 | 3 | Same as expert execution result in the left column |
| 134 | A51 Manage production | 5 | Update "criteria for new safety operating condition" (as {b}) | 5 | 2 | No; Input {b} |
| | | 6 | Select A7 and shift into it | 6 | 3 | Same as expert execution result in the left column |
| 135 | A7 Providing criteria, resource, information for LCE | 7 | Update "The criteria for operation according to instruction upside on LCE" (as {c}) | 7 | 2 | No; Input {c} |
| | | 8 | Select A1 and shift into it | 8 | 3 | Same as expert execution result in the left column |
| 136 | A1 Manage LCE | 9 | Skip | 9 | 2 | Skip; ∵ only shift to upper layer due to the protocol |
| | | 10 | Select A0 and complete this MOC when shift into it | 10 | 3 | Same as expert execution result in the left column |

which the experts acted or inputed into system through their MOC execution...(4); "#3": same meaning to "#1"...(5); "Step": step number described in Section 4.2...(6); "System recorded log": log which recorded the system action and inputs from the staffs into system...(7).

Each column is belonged to one of three groups. The columns of a group on the experts manually archived log [2] were described in (3)-(4), the columns of another group on the archived log using the proposed method were described in (5)-(7), and the two groups refer the common item columns of (1)-(2).

The cell in "System recorded log" column on the row which the Step column was 3 has two values separated by ";", the left side means simple result of Skip / Yes / No. The right side indicates the reasons for omission if Skip; the contents of change, consideration or execution if Yes; input the reason which judged as RIK if No.

We confirmed that the archived log of our system using our method described in Section 4.2 was as same level as traditional manner which the experts analyzed the entire 136 activity included the partial analysis of Table 2 and Table 3. Therefore, we concluded that our system can record log as same level as the log that the experts analyzed. As activity transition order, operation contents and its results for each activity also were saved into the system DB, so the conclusion of the assessment was that backward trace also is possible.

## 6 Conclusion

The factors not to execute MOC at all are caused from background where insufficient recognition of MOC and no archive of documents and log, which may cause indirect causes of accidents in turn. To solve that problem, we proposed a method to archive log executed MOC, and designed and developed a support software that can change procedure of MOC flexibly according to your business rules and can acquire log included the MOC executed process order making cause analysis more effective.

And we confirmed validity whether or not the method can get log as same level as one with traditional manner by comparing the two set of log data acquired from both the experts and our method on the evaluation experiment. The result was concluded that the two set of log were in same level without problem.

## Acknowledgement

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